



## In-Depth Survey Report

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### Removing mortar with a die grinder with on-tool local exhaust ventilation

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Regional Training Center, Batavia, Ohio

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## Abstract

### Background

Workplace exposure to respirable crystalline silica can cause silicosis, a progressive lung disease marked by scarring and thickening of the lung tissue. Several construction materials, such as brick, block, mortar and concrete contain crystalline silica. Construction tasks that cut, break, grind, abrade, or drill those materials have been associated with overexposure to dust containing respirable crystalline silica. Tuckpointing (repointing) removes damaged mortar from joints in masonry walls and replaces it with new mortar to restore the wall. The use of grinders to remove mortar results in worker overexposure to respirable crystalline silica. NIOSH scientists are conducting a study to assess the respirable crystalline silica exposures associated with mortar removal when tools other than grinders are used.

### Assessment

NIOSH staff visited the Bricklayers and Allied Craftworkers' Southern Ohio-Kentucky Regional Training Center, Batavia, Ohio on December 20, 2017 and performed industrial hygiene sampling, which measured exposures to respirable dust and respirable crystalline silica while an apprentice bricklayer used a die grinder with on-tool local exhaust ventilation to remove mortar from a brick wall. The NIOSH scientists also observed the work process in order to understand the conditions that contributed to the measured exposure and collected air flow data.

### Results

Personal breathing zone respirable crystalline silica concentrations measured during 10 to 26-minute-long periods of mortar removal ranged from less than the limit of detection to 0.54 mg/m<sup>3</sup>; the average concentration was 0.22 mg/m<sup>3</sup>.

### Conclusions and Recommendations

On average, die grinder with on-tool local exhaust ventilation reduced respirable quartz exposures when compared to angle grinders tested in a previous study. However, the range of exposures measured during the tests described in this report indicate that there is room for improvement. Closer examination of the tool and control with video exposure monitoring might reveal which tool positions result in the best capture and which tool positions should be avoided to best control exposure. The results could be incorporated in training materials that accompany the on-tool hood.

The ridge on the outside of the vinyl hose cuff was not large enough to prevent the cuff from slipping out of the back of the holder. A better way of positioning the cuff to permit the bricklayer to keep it close to the work surface might be helpful. A flange added to the inlet of the cuff would keep it from slipping out of the back of the holder and improve capture. The Industrial Ventilation Manual [ACGIH 2013] describes an extractor head for cone wheels and mounted points that consists of an

annular slot at the base of the bit. Perhaps that design could be adapted to this tool and task.

## Introduction

### Background for Control Technology Studies

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry, various chemical manufacturing or processing operations, spray painting, and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concept techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

### Background for this Study

Crystalline silica refers to a group of minerals composed of silicon and oxygen; a crystalline structure is one in which the atoms are arranged in a repeating three-dimensional pattern [Bureau of Mines 1992]. The three major forms of crystalline silica are quartz, cristobalite, and tridymite; quartz is the most common form [Bureau of Mines 1992]. Respirable crystalline silica refers to that portion of airborne crystalline silica dust that is capable of entering the gas-exchange regions of the lungs if inhaled; this includes particles with aerodynamic diameters less than approximately 10 micrometers ( $\mu\text{m}$ ) [NIOSH 2002]. Silicosis, a fibrotic disease of

the lungs, is an occupational respiratory disease caused by the inhalation and deposition of respirable crystalline silica dust [NIOSH 1986]. Silicosis is irreversible, often progressive (even after exposure has ceased), and potentially fatal. Because no effective treatment exists for silicosis, prevention through exposure control is essential. Silicosis is associated with a higher risk of tuberculosis and other lung disease [Parks et al. 1999]. Silica has been classified as a known human carcinogen by the International Agency for Research on Cancer [IARC 1997]. Occupational exposure to respirable crystalline silica has been associated with kidney disease and autoimmune diseases, such as rheumatoid arthritis [Stratta et al. 2001, Parks et al. 1999].

Crystalline silica is a constituent of several materials commonly used in construction, including brick, block, and concrete. Many construction tasks have been associated with overexposure to dust containing crystalline silica [Chisholm 1999, Flanagan et al. 2003, Rappaport et al. 2003, Woskie et al. 2002]. Among these tasks are tuckpointing, concrete cutting, concrete grinding, abrasive blasting, and road milling [Nash and Williams 2000, Thorpe et al. 1999, Akbar-Kanzadeh and Brillhart 2002, Glindmeyer and Hammad 1988, Linch 2002, Rappaport et al. 2003].

Tuckpointing (repointing) removes damaged mortar from joints in masonry walls and replaces it with new mortar to restore the wall and improve its resistance to the weather, prolonging its life and preventing water from penetrating the building envelope and causing damage to the structure [Gerns and Wegener 2003]. Mortar is typically removed to a depth of at least ¾-inch (in) (19 millimeters [mm]) using electric grinders, although hammers and chisels can be used [Gerns and Wegener 2003]. Other power tools are also available, including mortar routers, a die grinder with diamond tools, a hammer drill and mortar chisel, and a saw [Yasui et al. 2003, ICS 2016, Robert Bosch Tool Corporation 2016, Arbortech 2016]. Mortar mixes contain Portland cement, lime, and sand in various proportions depending on the strength required. Type N mortar, with a minimum required compressive strength of 750 pounds per square inch (PSI), is recommended for use in exterior, above grade walls and is durable and flexible enough to replace deteriorated mortar in most walls [IMI 2002, PCA 2002, Gerns and Wegener 2003].

The use of grinders to remove mortar results in worker exposure to respirable crystalline silica 2 to 1500 times the NIOSH Recommended Exposure Limit (REL) of 50 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) [OSHA 2013]. Even with engineering controls (i.e., on-tool local exhaust ventilation [LEV]), the use of a respirator with an assigned protection factor of 10 is still required [Collingwood and Heitbrink 2007]. In its Preliminary Economic Analysis for the Proposed Rule for Occupational Exposure to Respirable Crystalline Silica [OSHA 2013], the Occupational Safety and Health Administration (OSHA) reported the results of 151 8-hour samples for respirable crystalline silica for tuckpointers. Those sample results were organized into three exposure categories: outdoors, uncontrolled; outdoors, some form of LEV dust control; and under other working conditions (e.g., with limited air movement, or with inadequate attempts at dust control). Respirable crystalline silica exposures for uncontrolled, outdoor tuckpointing (83 samples) ranged from 12 to 12,616  $\mu\text{g}/\text{m}^3$ , with a mean of 1,601  $\mu\text{g}/\text{m}^3$  and a median of 631  $\mu\text{g}/\text{m}^3$ ; 59 (71%) of the

samples exceeded 250  $\mu\text{g}/\text{m}^3$ . Tuckpointers working outdoors with some form of LEV (56 samples) experienced respirable crystalline silica exposures from 10 to 6,196  $\mu\text{g}/\text{m}^3$ , with a mean of 368  $\mu\text{g}/\text{m}^3$  and a median of 70  $\mu\text{g}/\text{m}^3$ . Fifteen (27%) of those samples were greater than five times the NIOSH REL. Workers tuckpointing in other conditions<sup>1</sup> (12 samples) had respirable crystalline silica exposures from 146 to 75,153  $\mu\text{g}/\text{m}^3$ , with a mean of 7,198  $\mu\text{g}/\text{m}^3$  and a median of 793  $\mu\text{g}/\text{m}^3$ . Ninety-two percent (11) of the samples in that category exceeded 250  $\mu\text{g}/\text{m}^3$ .

The tuckpointing study by Collingwood and Heitbrink [2007] reported several conditions that must be met in order for tool-mounted LEV on tuckpointing grinders to be effective: "The distance between the exhaust take-off and the uncut mortar must be minimized...the grinding wheel needs to be moved against its natural rotation so the debris is directed in the exhaust take-off...the worker must periodically stop grinding and take action to maintain [vacuum cleaner] airflow." The authors also noted that exposures increased when the distance between the tool-mounted LEV and the surface of the mortar increased, such as during plunge cuts, and when deteriorated, missing mortar provided a means for dust to escape. The OSHA sampling data for tuckpointers working outdoors with some form of LEV and the conditions that must be met for the LEV to be effective indicate that there is a need to either improve the LEV for grinders or identify tools other than grinders that may be used to remove mortar effectively and efficiently while minimizing tuckpointers' silica exposures. The intent of this site visit was to evaluate the use of a powered saw with a modified shroud as a potential alternative to tuckpointing with a grinder.

## Plant and Process Description

The BAC training center resources include expert trainers and skilled apprentices to test tools and provide feedback about their utility and acceptability, as well as a suitable environment in which to assess the tools' performance and associated exposures. In addition, the trainers are experienced in vocational training curriculum development and assessment. The Related Technical Instruction (RTI) portion of the training for the different bricklayer trades is conducted at this facility. RTI includes classroom and practical instruction in tasks such as building and tuckpointing brick walls.

A brick wall was built inside the training center using block, bricks, and Type N mortar. The mortar was allowed to cure for at least 21 days before it was removed. The wall, built in the shape of the letter C, included four inside corners (Figure 1). The wall was approximately 1.5 meters (m) high, composed of 16 rows of brick on top of a row of block on a concrete base. The three closed sides of the wall were approximately 4.0 m long, while portions on both sides of the opening were approximately 0.60 m long.

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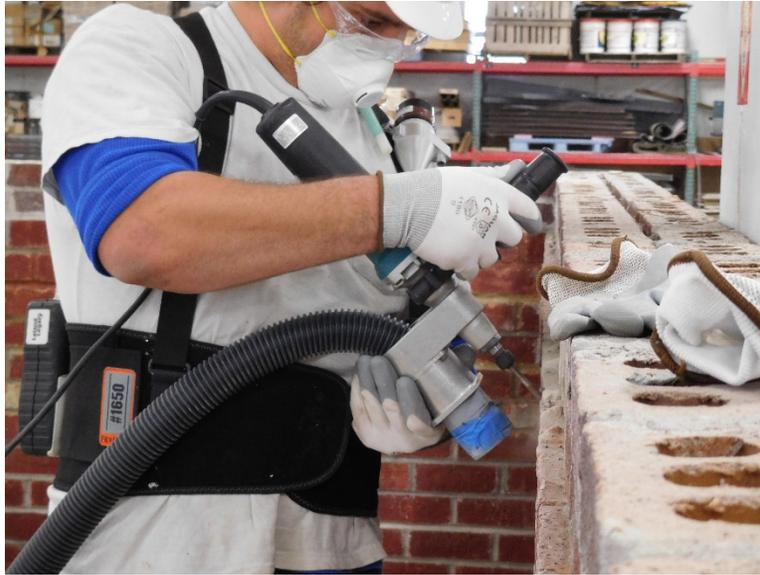
<sup>1</sup> Including in areas with limited air circulation (e.g., a courtyard, or between a wall and a plastic tarp) or where dust controls are attempted in a manner offering little or no benefit (e.g., wetting the wall before grinding, or using damaged LEV equipment).



**Figure 1 - Wall used for tests (NIOSH photo)**

Air samples for respirable dust and respirable crystalline silica were collected while an apprentice bricklayer removed mortar from the wall. The bricklayer wore a Northern Safety 7511 N-95 filtering facepiece respirator with an exhalation valve (Northern Safety Co., Inc., Utica, NY). Training, fit-testing, and medical clearance were performed by his employer. He donned and wore the respirator correctly. He also wore a hardhat, safety glasses, ear plugs, work boots, and work gloves.

The apprentice bricklayer removed mortar using a die grinder (model GDO800C, Makita U.S.A., Inc., La Mirada, CA) and ¼ inch by 3-1/2 inch (6.4 mm by 89 mm) diamond router bit (P/N GB14350, Industrial Contractors Supply Co., N. Huntingdon, PA). An on-tool LEV attachment (Brick & Tile Dust Controller, P/N GB-BDC, Industrial Contractors Supply Co., N. Huntingdon, PA) was attached to the grinder. It held a vinyl hose cuff that was threaded on the inside to accept a 1-1/2 inch (38 mm) diameter vacuum cleaner hose. A ridge on the outside of the cuff held it in place in the LEV attachment. The apprentice was instructed to use the tool to remove mortar from head and bed joints and include inside corners. Samples were collected as described below while the apprentice bricklayer removed the mortar. The tool is shown in Figure 2.



**Figure 2 – Die grinder with on-tool exhaust hood (NIOSH photo)**

The vacuum cleaner hose was connected to a pre-separator (model DC 2800, Dustcontrol, Inc., Wilmington, NC), which was connected via a 2-in diameter hose to a vacuum cleaner (model DC 2900eco, Dustcontrol, Inc, Wilmington, NC), equipped with a part number 42029 prefilter and part number 42027 class-H<sup>2</sup> final filter (Dustcontrol, Inc, Wilmington, NC). The pre-separator and vacuum cleaner are shown in Figure 3. A new filter and prefilter were used during this day of testing. The use of a cyclonic pre-separator has been shown to reduce the accumulation of dust and debris on the filter in the vacuum cleaner, which helps to maintain a steady airflow [Heitbrink and Santalla-Elias 2009].

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<sup>2</sup> Filtration efficiency is 99.995%, according to standard EN 60335.

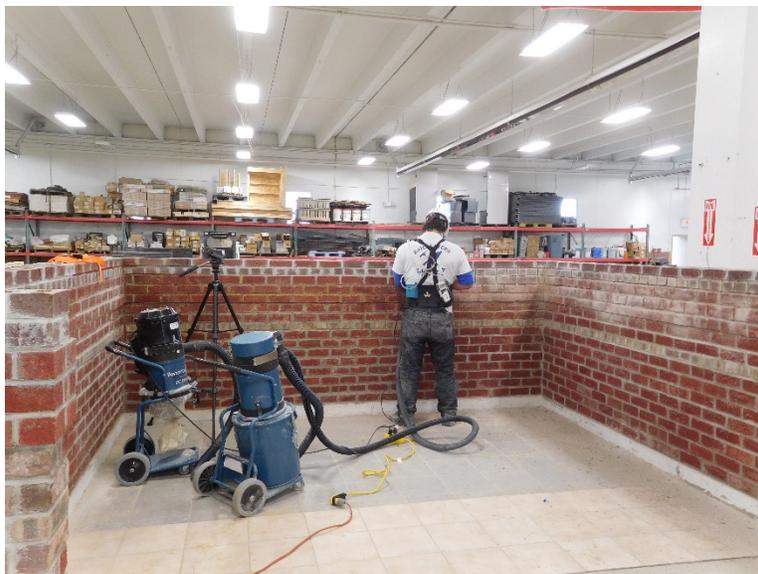


Figure 3 - Vacuum cleaner (left) and pre-separator (right) (NIOSH photo)

## Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended occupational exposure limits (OELs) when evaluating chemical, physical, and biological agents in the workplace.

Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus can increase the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S.

Department of Labor OSHA Permissible Exposure Limits (PELs) [CFR 2003] are occupational exposure limits that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH RELs are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the Threshold Limit Values<sup>®</sup> (TLVs<sup>®</sup>) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH<sup>®</sup>), a professional organization [ACGIH 2018]. ACGIH TLVs are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline “to assist in the control of health hazards.” Workplace Environmental Exposure Levels (WEELs) are recommended OELs developed by the American Industrial Hygiene Association, another professional organization. WEELs have been established for some chemicals “when no other legal or authoritative limits exist.” [AIHA 2007].

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

### **Crystalline Silica Exposure Limits**

When dust controls are not used or maintained or proper practices are not followed, respirable crystalline silica exposures can exceed the NIOSH REL, the OSHA PEL, or the ACGIH TLV. NIOSH recommends an exposure limit for respirable crystalline silica of 0.05 mg/m<sup>3</sup> as a TWA determined during a full-shift sample for up to a 10-hour (hr) workday during a 40-hr workweek to reduce the risk of developing silicosis, lung cancer, and other adverse health effects [NIOSH 2002]. When substituting less hazardous materials for crystalline silica (where feasible) and source controls cannot keep exposures below the NIOSH REL, NIOSH also recommends minimizing the risk of illness that remains for workers exposed at the REL by using appropriate respiratory protection, and by making medical examinations available to exposed workers [NIOSH 2002]. In March 2016, OSHA

issued a new PEL of 0.05 mg/m<sup>3</sup> for 8-hr TWA exposures [81 Fed. Reg.<sup>3</sup> 16285 (2016)]. The ACGIH TLV for  $\alpha$ -quartz and cristobalite (respirable fraction) is 0.025 mg/m<sup>3</sup> [ACGIH 2018]. The TLV is intended to mitigate the risk of pulmonary fibrosis and lung cancer.

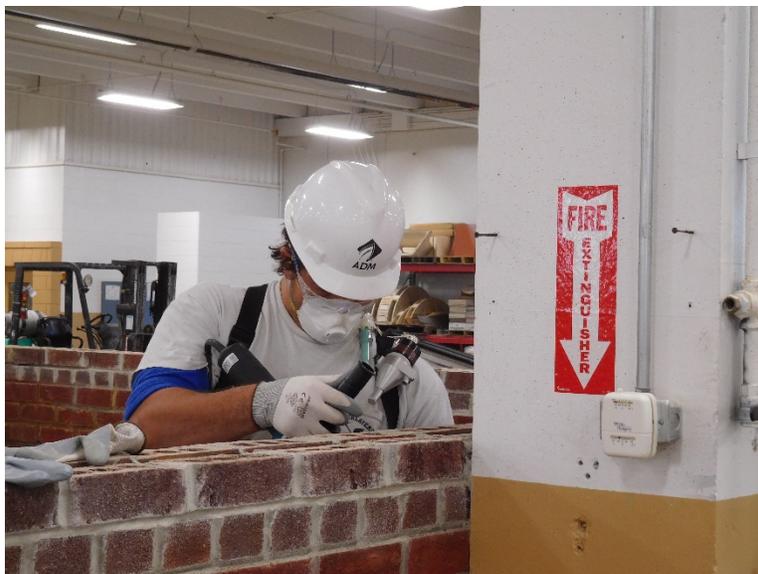
## Methodology

Personal breathing zone (PBZ) and area air samples for respirable dust and respirable crystalline silica were collected while an apprentice bricklayer used a die grinder with on-tool LEV to remove mortar from a brick wall. The bricklayer repeated the mortar removal process during 6 sampling periods, which ranged from 10 to 26 minutes long. Figure 4 shows the bricklayer wearing PBZ air samplers.

PBZ air samples for respirable particulate were collected at a flow rate of 9 liters/minute (L/min) using a battery-powered sampling pump (Leland Legacy sampling pump, SKC, Inc., Eighty-Four, PA) calibrated before and after sampling. The sampling pump was attached to the waistband of a back-support vest (Model 1650, Ergodyne, St. Paul, MN). The pump was connected via Tygon<sup>®</sup> tubing to a pre-weighed, 47-mm diameter, 5-micron ( $\mu\text{m}$ ) pore-size polyvinyl chloride (PVC) filter supported by a backup pad in a three-piece conductive filter cassette sealed with a cellulose shrink band (in accordance with NIOSH Methods 0600 and 7500) [NIOSH 1998, NIOSH 2003]. The front cover of the cassette was removed and the cassette was attached to a respirable dust cyclone (BGI GK 4.162 cyclone, MesaLabs, Butler, NJ). At a flow rate of 9 L/min, the GK 4.162 cyclone has a 50% cut point of ( $D_{50}$ ) of 3.91  $\mu\text{m}$ , and conforms to the respirable sampling convention at flow rates between 8.5 and 9.5 liters per minute [HSL 2012].  $D_{50}$  is the aerodynamic diameter of the particle at which penetration into the cyclone declines to 50% [Vincent 2007]. The cyclone was clipped to the suspender strap of the back-support vest near the bricklayer's head and neck within the breathing zone (Figure 4). Area air samples were collected using the same sampling method, except that the sampling pump and cyclone were placed in holders mounted atop two tripods at about breathing zone height, 5 ft (1.5 m) above the ground. One tripod with the sampling apparatus was placed 8 ft (2.4 m) from the end of the brick wall on the right. The other tripod with the sampling apparatus was placed 6.5 ft (2.0 m) from the end of the brick wall on the left. A bulk sample of mortar was also collected in accordance with NIOSH Method 7500 [NIOSH 2003].

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<sup>3</sup> *Federal Register*. See Fed. Reg. in references.



**Figure 4 - Worker wearing air samplers**

The filter samples were analyzed for respirable particulates according to NIOSH Method 0600 [NIOSH 1998]. The PVC filters were allowed to equilibrate for a minimum of two hours before weighing. A static neutralizer was placed in front of the balance and each filter was passed over this device before weighing. The filters were weighed on a balance (model number XP6, Mettler-Toledo LLC, Columbus, OH). The sequence specific limit of detection (LOD) and the limit of quantitation (LOQ) were determined using seven media blanks. The LOD is three times the standard deviation of the media blank weight differences. The LOQ is ten times the standard deviation of the media blank weight differences. The limit of detection (LOD) was 20  $\mu\text{g}/\text{sample}$ . The limit of quantitation (LOQ) was 76  $\mu\text{g}/\text{sample}$ .

Samples were prepared and analyzed following NIOSH Method 7500 [NIOSH 2003], as noted. Each filter was removed from the air cassette and folded two times into a wedge-shaped pocket to contain the particulate inside. A drop of 2-propanol (IPA) was added to the inside of the cassette lid and the back side of the sample filter was used to wipe the interior of the sampling cassette. The filter was transferred to a 15-mL sample vial. The filter was dissolved by addition of 8 mL of tetrahydrofuran (THF) to the sample vial. The samples were mixed by vortex. The sample vial was covered with aluminum foil and placed in an ultrasonic bath for ten minutes. The sample suspension was transferred to a silver-membrane filter. First, a silver-membrane filter was placed in the vacuum filtration unit. Next, 2 mL of THF solvent was placed onto the filter. The sample suspension was vortexed and immediately added onto the silver membrane filter. The sample vial was rinsed with three separate portions THF. Each rinse was added to the sample on top of the silver membrane filter. Finally, vacuum was applied to deposit the sample suspension onto the filter. The silver-membrane filter was transferred to a sample plate and placed in the automated sample changer for analysis by X-ray diffraction. The LOD for quartz and cristobalite was 5  $\mu\text{g}/\text{sample}$ . The LOD for tridymite was 10

µg/sample. The LOQ for quartz was 18 µg/sample. The LOQ for cristobalite was 17 µg/sample. The LOQ for tridymite was 33 µg/sample.

In this sample set, the maximum air sample volume collected was 234 L. At the LOD for quartz of 5 µg/sample, the minimum detectable quartz concentration was 0.021 mg/m<sup>3</sup>, 43% of the NIOSH REL of 0.05 mg/m<sup>3</sup>. The minimum quantifiable quartz concentration at the LOQ of 18 µg/sample was 0.077 mg/m<sup>3</sup>, or about 1.5 times the NIOSH REL of 0.05 mg/m<sup>3</sup>. The minimum detectable respirable dust concentration on the filter samples at the LOD of 20 µg/sample was 0.085 mg/m<sup>3</sup>, while the minimum quantifiable concentration at the LOQ of 76 µg/sample was 0.32 mg/m<sup>3</sup>.

A qualitative x-ray diffraction scan was acquired using a portion of the bulk sample, processed through a 45 µm sieve. Approximately 0.5 g of sample was ground and wet sieved through a 10 µm sieve using 2-propanol. The alcohol was evaporated in a drying oven. Approximately 1 mg of sieved-dried sample was weighed into a 15-mL test tube. Approximately 10 mL of 2-propanol was added into the test tube to create a suspension. The test tube was placed in an ultrasonic bath for about 10 minutes until agglomerated particles were broken up. The sample suspension was vortexed and immediately re-deposited onto a 25-mm diameter silver membrane filter, as follows: First, a silver membrane filter was placed in the vacuum filtration unit. Next, 2 mL of 2-propanol was added into the filtration funnel, followed by the sample suspension and test tube rinses. Finally, vacuum was applied to re-deposit the suspension onto the filter. The silver membrane filter was transferred to a sample plate and placed in the automated sample changer for analysis by X-ray diffraction. The LOD for quartz and cristobalite in the bulk dust sample was 0.5%. The LOD for tridymite was 1%. The LOQ for quartz and cristobalite was 1.7%. The LOQ for tridymite was 3.3%

Real-time PBZ respirable dust sampling was performed using an aerosol photometer (SidePak AM510 aerosol monitor, TSI Inc., Shoreview, MN) with a 10-mm nylon respirable dust cyclone. The instrument's internal sampling pump was calibrated before and after each day's use to operate at a flow rate of 1.7 L/min. The SidePak was clipped to waistband of the back-support vest and the cyclone was clipped to the shoulder strap in his breathing zone. A length of Tygon tubing connected the cyclone and the instrument. The SidePak was set to log data every second during the sampling period.

A data-logging weather station (Kestrel 4500, Nielsen-Kellerman, Boothwyn, PA) mounted on top of a tripod recorded temperature, relative humidity, and air speed near the work area. The weather meter was approximately 60 in (1.5 m) off the ground. The weather meter was programmed to record data every minute.

Following the site visit, the airflow through the system consisting of the hood mounted on the saw, hose, and vacuum cleaner with clean filters was measured in the laboratory by inserting a delta tube (model 307BZ-11-A0, Midwest Instrument, Sterling Heights, MI) in line in the hose between the hood and the vacuum cleaner,

in accordance with the manufacturer's recommendations. The differential pressure across the delta tube was measured with a Magnehelic pressure gauge (model 2050, Dwyer Instruments, Inc., Michigan City, IN), and the reading was used to calculate the airflow rate in accordance with the delta tube manufacturer's manual.

## **Results**

The bulk sample of mortar contained 32% quartz by weight. No cristobalite or tridymite were found in the bulk dust sample. No cristobalite or tridymite were found in any of the air samples.

The results of air sampling for respirable quartz dust are presented below in Table 1. Respirable quartz dust found in the area samples may reflect the proximity of the area sample to the location of the work on the brick wall during that trial. PBZ respirable quartz dust ranged from less than the LOD to 0.54 mg/m<sup>3</sup>.

Table 1 – Respirable Quartz Dust Results

Trial	Location	Quartz (ug/sample)	Duration (min)	Average Flow (L/min)	Vol (L)	Quartz Concentration (mg/m <sup>3</sup> )
1	PBZ	ND	25	8.9	223	---
	Area Left	ND	25	9.0	225	---
	Area Right	ND	25	9.0	225	---
2	PBZ	ND	26	8.9	231	---
	Area Left	ND	26	9.0	234	---
	Area Right	ND	26	9.0	234	---
3	PBZ	45	25	8.9	223	0.20
	Area Left	ND	25	9.0	225	---
	Area Right	ND	25	9.0	225	---
4	PBZ	51	25	8.9	223	0.23
	Area Left	ND	25	9.0	225	---
	Area Right	ND	25	9.0	225	---
5	PBZ	120	25	8.9	223	0.54
	Area Left	20	25	9.0	225	0.089
	Area Right	(6.1)	25	9.0	225	(0.027)
6	PBZ	38	25	8.9	223	0.17
	Area Left	ND	25	9.0	225	---
	Area Right	ND	25	9.0	225	---
7	PBZ	35	10	8.9	89	0.39
	Area Left	ND	10	9.0	90	---
	Area Right	ND	10	9.0	90	---

Notes: PBZ means personal breathing zone. Values in parentheses indicate results between the limit of detection and the limit of quantification. These are trace values with limited confidence in their accuracy. ND means not detected, a value below the limit of detection. Dashed lines means the concentration was not calculated because the result was less than the limit of detection.

The results of air sampling for respirable dust are presented below in Table 2. Respirable dust concentrations in the PBZ samples ranged from 0.30 mg/m<sup>3</sup> to 2.3 mg/m<sup>3</sup>. The quartz content in the PBZ samples was less than 24% by weight.

Table 2 – Respirable Dust Results

Trial	Location	Respirable Dust (ug/sample)	Duration (min)	Average Flow (L/min)	Vol (L)	Respirable Dust Concentration (mg/m <sup>3</sup> )
1	PBZ	(67)	0:25	8.9	223	(0.30)
	Area Left	(37)	0:25	9.0	225	(0.16)
	Area Right	(37)	0:25	9.0	225	(0.16)
2	PBZ	77	0:26	8.9	231	0.33
	Area Left	(37)	0:26	9.0	234	(0.16)
	Area Right	(57)	0:26	9.0	234	(0.24)
3	PBZ	230	0:25	8.9	223	1.03
	Area Left	ND	0:25	9.0	225	---
	Area Right	(37)	0:25	9.0	225	(0.16)
4	PBZ	200	0:25	8.9	223	0.90
	Area Left	(27)	0:25	9.0	225	(0.12)
	Area Right	ND	0:25	9.0	225	---
5	PBZ	510	0:25	8.9	223	2.29
	Area Left	(57)	0:25	9.0	225	(0.25)
	Area Right	(57)	0:25	9.0	225	(0.25)
6	PBZ	240	25	8.9	223	1.08
	Area Left	(47)	25	9.0	225	(0.21)
	Area Right	(67)	25	9.0	225	(0.30)
7	PBZ	190	0:10	8.9	89	2.13
	Area Left	(57)	0:10	9.0	90	(0.63)
	Area Right	ND	0:10	9.0	90	---

Notes: PBZ means personal breathing zone. ND means not detected, a value below the limit of detection. Dashed lines means the concentration was not calculated because the result was less than the limit of detection.

The second trial included 5 minutes during which the bit was changed. The fifth trial included an inside corner. During the sixth trial, the bricklayer had to tighten the bit, but the pumps were stopped so that pause was not included in the sampling time.

Real time data were recorded during trials 3 – 7. The data are presented in Table 3. Average real-time personal breathing zone respirable dust samples during each sampling period ranged from 0.519 mg/m<sup>3</sup> to 1.21 mg/m<sup>3</sup>.

Table 3 – Direct-Reading Respirable Dust Results

Sampling Period	Duration (min:sec)	Average (mg/m <sup>3</sup> )	Minimum (mg/m <sup>3</sup> )	Maximum (mg/m <sup>3</sup> )
3	25:23	0.519	<0.001	12.1
4	25:07	0.622	0.198	17.5
5	24:53	1.21	0.209	19.7
6	25:17	0.822	0.206	14.8
7	10:30	1.12	0.238	9.41

<0.001 mg/m<sup>3</sup> indicates a result less than the manufacturer’s reported sensitivity of the instrument.

The average temperature was 58°F, and the average relative humidity was 44%. The weather meter did not detect any air movement. Lower readings may be taken down to 79 ft/min (0.4 m/sec) with the weather meter used here.

Airflow through the on-tool hood with the grinder and vacuum cleaner running was 97 cfm. The hose between the pre-separator and the tool was 1.5 in (3.8 cm) in diameter. The calculated average velocity in a 1.5 in (3.8 cm) diameter hose at a flow rate of 97 cfm (2.8 m<sup>3</sup>/min) is approximately 7900 feet per minute (fpm) 40 (m/sec).

## Discussion

The differences in the respirable dust results between the direct reading instrument and the gravimetric samples may be due to the fact that the The SidePak AM510 is calibrated against a gravimetric reference using the respirable fraction of standard ISO 12103-1, A1 test dust (Arizona Test Dust), which has a different composition and size distribution, and different light scattering characteristics to the mortar dust. The average results from the real-time samples followed the same trend as the gravimetric sample results, increasing for trials 5 and 7, for example.

This die grinder with local exhaust ventilation was able to remove mortar from the wall while generating lower exposures to respirable quartz than an angle grinder with LEV, on average. For example, Meeker et al. [2009] evaluated two tuck-pointing angle grinders with and without LEV. Like this test of a die grinder, their trials with LEV lasted about 25 minutes. The mean PBZ respirable quartz concentration for one angle grinder was 0.47 mg/m<sup>3</sup> (range 0.28 mg/m<sup>3</sup> – 0.85 mg/m<sup>3</sup>); for the other angle grinder, the mean PBZ respirable quartz concentration was 0.33 mg/m<sup>3</sup> (range 0.19 mg/m<sup>3</sup> – 0.50 mg/m<sup>3</sup>) [Meeker et al. 2009]. In comparison, the PBZ respirable quartz concentration for the die grinder tested here ranged from <LOD to 0.54 mg/m<sup>3</sup>, with a mean of 0.22 mg/m<sup>3</sup>. In order to calculate the mean, the value of LOD/sqrt2 was divided by the air volume in Trials 1 and 2 to calculate a concentration when the respirable quartz mass was less than the LOD [Hornung and Reed 1990]. The mean respirable quartz mass measured during tests of the die grinder represents a 53% reduction when compared to one angle grinder and a 33% reduction compared to the other.

The transport velocity of approximately 7900 feet per minute (fpm) (40 m/sec) should prevent clogging due to dust settling in the duct with clean filters in the vacuum cleaner. The ACGIH industrial ventilation manual recommends a transport velocity of 3500 to 4000 fpm for "average industrial dust" (e.g., granite or limestone dust, brick cuttings, silica flour) [ACGIH 2013].

The range observed in measured respirable dust and respirable quartz concentrations may be due to the directionality of the dust ejected by the grinding process in relation to the position of the exhaust hood mounted on the tool, the distance between the hood and the grinding bit and work surface in certain orientations, or the hood being blocked by the brick wall in some positions. For example, in Figure 5 the hood inlet is close to the work surface, and capture is very good, while the hood is farther from the work surface in Figure 6. Blue paper tape prevented the vinyl hose cuff from slipping out the back of the holder.



**Figure 5 – Hood close to work surface**



Figure 6 - Hood far from work surface

## Conclusions and Recommendations

On average, die grinder with on-tool local exhaust ventilation reduced respirable quartz exposures when compared to angle grinders tested in a previous study. However, the range of exposures measured during the tests described in this report indicate that there is room for improvement. Closer examination of the tool and control with video exposure monitoring might reveal which tool positions result in the best capture and which tool positions should be avoided to best control exposure. The results could be incorporated in training materials that accompany the on-tool hood.

The ridge on the outside of the vinyl hose cuff was not large enough to prevent the cuff from slipping out of the back of the holder. A better way of positioning the cuff to permit the bricklayer to keep it close to the work surface might be helpful. A flange added to the inlet of the cuff would keep it from slipping out of the back of the holder and improve capture. The Industrial Ventilation Manual [ACGIH 2013] describes an extractor head for cone wheels and mounted points that consists of an annular slot at the base of the bit. Perhaps that design could be adapted to this tool and task.

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